

Advanced Tool for Training Architect Students in Efficient Energy Management

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Abstract

The LEMA presents Strategy II, the new version of his CAL software in thermal design of building. Based on his latest experiences using the first prototypes, the present programme provides an complete human interface and interesting tools for decision taking. A first educational experience with this software is described. Strategy II has been studied in 1990 by two twin teams: one is the LEMA (Laboratoire d'Etudes Méthodologiques Architecturales) and the other one is the CTE (Centre des Technologies de l'Education), parts of the University of Liège, in Belgium.

Introduction: Architecture and Energy

One of the most accepted models of architectural design is a highly cyclical trial and error process. Therefore the best way to teach architectural design is to front students with design situations and help them define their own rules through the development of architectural solutions. More specifically, the problem is not easier when teaching about energy to students in architecture. To study the classical problem of a standard dwelling house in a steady state thermal balance, students have to know about 8 main performances, defined by more than 80 different parameters.

When teaching these two matters, the LENIA, Laboratory of Architectural Methodology Studies of the University of Liège, meets two similar problems.

1. The architecture students, constrained with high level thermal courses forget the link between their mathematical relations and the material reality of their building project. When drawing a window on an elevation draft in the composition course, they forget their conclusions written after long calculations during the thermal course the day before.
2. Stressed by the pressure of the economics, architects don't spend any time to understand a matter such as thermal performances which they think is too complex. In Belgium, the Wallonian Region asks for a simple thermal evaluation which is checked before each building allowance to reduce important heat loss. Professional architects often fill out the form at the last minute, without understanding what they write and sometimes cheat to obtain an acceptable value for final evaluation!

The CAL software described in this paper provides an adapted tool for students or architects in thermal design of building.

Historical Account

The first version of this software, now called Strategy 0, has been developed by the LEMA in April, 1984. The research was called "Basic Characteristics for Low cost Houses in order to Reduce the Energy Consumption for Heating". It helped the architect to design the thermal comfort of his house project with the new conditions of the energy crisis. This first attempt allowed a very caricatured building description, only useful for standard Belgian houses. Strategy 0 was supported by the best price/quality ratio hardware, the Sirius PC, with a complete graphical interface. This one was not powerful enough to get a real interactive programme.

It was used to easily estimate the thermal performances of social buildings in front of larger programmes, like LP1 to 4. It was able to calculate the complete energy behavior of any building, but heavy to use because to run it they needed to input lots of data.

In 1988, the LEMA translated Strategy on a new running platform, which was a personal Apple computer. The goal was to bring it on a powerful and popular computer. At this moment, Macintosh computers are spread throughout Architects' offices in Belgium. With the new power of this Strategy 1 version, the interactive side of the software appeared and the LEMA could find and test new ideas about training in building energy. The Wallonian Authorities, editing the thermal rules for building design, have understood the opportunity of such an educational software. The year after, the LEMA was asked to create Strategy 11.

Methodology of the Strategy II design

This part of the research programme is achieved with the CTE. Department of Educational Technology, Psychology and Educational Science Division of the University of Liège.

The first evaluation of Strategy has been realized by the MEDA software. MEDA means "Evaluation Methodology of Training Software" and is supported by the European Communities in the Task Force programme.

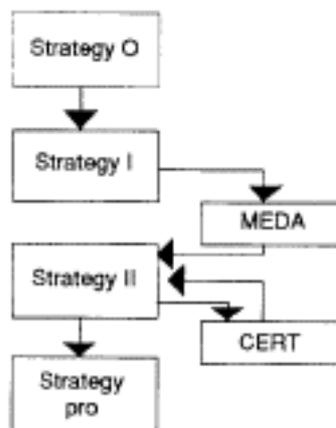


Figure 1: transfer to Strategy II with MEDA

MEDA suggests an operational method for the construction of an evaluation grid by developers on their own objectives. It brings interesting features to aid decision making about the design of a training software. The grid showed the defaults of the version one we had to improve and the qualities we had to develop in the second version.

The main quality is that the user can use its own strategy to discover the thermal concepts. This meets the learning objectives of the LEMA as well as those of the University of Liège. The user can play with the multi windowing interface and have access any time to any parameter. The software respects the individual rhythm of work. The user spends the time he wants on each part of the training tool: he can stop and resume whenever.

He controls the information quantity and chooses the only data he will work on. Information is based on graphical presentations and is set in a coherent structure. Computer science knowledge is not needed to use Strategy. It uses an error manager which prevents any user's fault or misunderstanding.

The MEDA grid also gave us some purposes for writing the user's guide as well as suggestions for the information board which helps the student in line.

Programming environment

To respond to the conclusions of the MEDA assessment, Strategy is developed with a double programming language. The calculation module is written with the Pascal sequential language as in [he previous versions. The complete human interface is based on SuperTalk, an object oriented language available on Macintosh computers. This dual approach, more widely used now, allows fast calculation and offers an ergonomic interface to the user at the same time. SuperTalk is now the most complete environment for multimedia applications. It creates a multi windowing interface, managed with the mouse control of graphical elements and using the HyperText facilities. This interface based on a window and card hierarchy leaves an open door to any further didactical developments. It can launch documents from many other applications and read data, pictures or sounds from a CD ROM. This allows interactive illustrations about one particular studied subject. New catalogs, more complete information panels or other parallel tools can easily be added and linked to the actual stack presentation.

Strategy is a standalone application of 950K for its standard version II. It runs on any Macintosh computer with 2Mb RAM and a 20Mb hard disk. To fasten calculation time, it's more convenient to use a II Cx model at least.

General structure of the programme

The software allows the learner to edit all parameters about a theoretical building and the surrounding site. It then draws the inference from the data proposed by the user, following Wallonian thermal regulations.

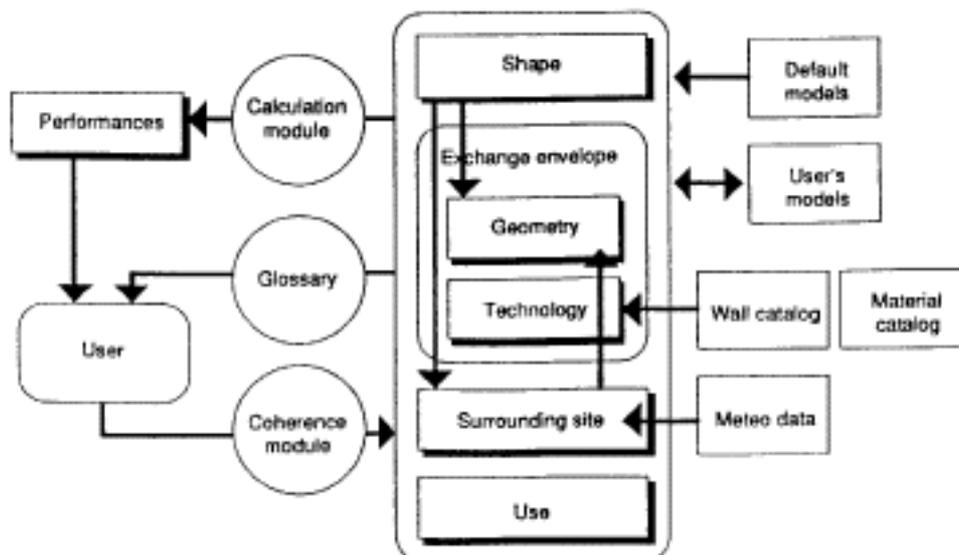


Figure 2: general structure of Strategy II

The 80 primary parameters are distributed into 5 main screens which are:

- the shape descriptor, to define the heated volume
- the geometry adjuster, for glazing areas, party walls and opaque surfaces....
- the technology descriptor, to give the wall compositions, thermal and optical conditions
- the way of use, to fix the comfort temperature and domestic heat
- the surrounding site, to draw the solar masks, to choose the meteorological data, the orientation of the building....

The permanent control board displays the main results, calculated on user's order, whenever during the design process. For its evaluations, the calculation module looks up the input parameters edited by the user in the five previous screens. Each work domain can be described with the help of parallel tools and catalogs as the meteorological data, the material thermal description list or the wall conduction evaluator. The coherence module analyses, corrects or stops each user's input. The glossary gives the definition of any word displayed on the screen. Beside a configuration catalog proposing standard building models, the user can save and load personal representations.

Each rectangular box of figure 2 corresponds to a screen window of the programme. Let's have a look at the content of each box.

Contents of Strategy II

1. The performance board

This screen shows the values of the 8 main control indices of the building model. The 3 most important, which are the heat energy needs (E), the global heat loss coefficient (K) and the solar recuperating factor (KRo), are also evaluated by 3 indicators. These allow to see the gap between the present theoretical description and the previous one.

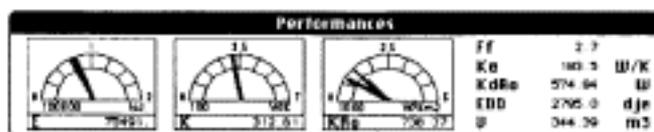


Figure 3: the performance board

The others are the shape factor value describing the heated volume (H), the wall heat loss coefficient (Ke), the higher gap of solar energy between winter and summer (K:Ro), the equivalent degree days on which the calculation method is based (EDD) and the heated volume (V).

2. The shape description

Ten parameters linked together, allow to draft the heated volume of the theoretical model. All shape characteristics are illustrated by a self explanatory icon (number of levels, roof slope, _).

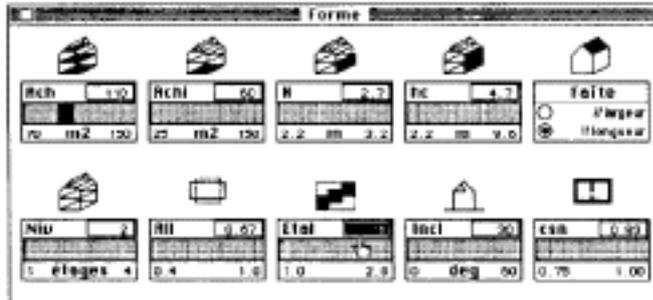


Figure 4: the shape window

Why is Strategy called a formation tool? The best illustration of the didactic vocation is found here. For example, the student wants to analyze the incidence of the plan aspect factor (All) defined as the ratio of the house breadth to its length. By editing this parameter, the user can widely change the shape but he doesn't modify the heated floor area. This is the didactical way in front of the professional one which, enlarging a building, would grow the heated floor area at the same time. Here each parameter is as separated as possible from the others to see more easily its own inherence.

3. The wall description board

A. Geometry

By analyzing the shape, the computer can deduct the area of each envelope side. He yet needs some indications about the party walls and glazed areas.

		dir	Si	Pal	Sol	Pal	Smi	Sept
			m2		m2		m2	m2
0 - Sol		-	70.2	-	-	-	-	-
1 - Façade	mur 1	90	64.3	30	16.3	0	0	48.0
2 - Façade	toit 2	90	32.7	3	0	100	32.7	0
3 - Façade	mur 3	90	64.3	8	1.18	0	0	56.2
4 - Façade	mur 4	90	32.7	7	2.29	0	0	30.4
5 - Toiture	Toiture 5	90	41.7	0	0	-	-	41.7
6 - Toiture	Toiture 6	90	41.7	0	0	-	-	41.7
Technologie			S	Pa	Su	Prn	Sib	Sep
			277	0.34	20.7	0.17	32.7	2.0

Figure 5: the geometry board

B. Technology

This screen allows to describe the wall thermal parameters. The U coefficients are the classical conductions, the shading factor (fomb) takes into account solar protections or local solar masks, the 'Tv' parameter is the rate air change of each elementary surface of the

	U	Uopt	fomb	Tv	α	β	ϵ
	W/Km2	W/Km2		1/hm2			
0 - Sol	-	0.49	-	-	-	-	-
1 - Façade Mur1	1.97	0.49	0.9	20	0.70	0.9	0.90
2 - Façade Toit1	1.97	0.49	0.9	20	0.70	0.9	0.90
3 - Façade Bardage1	1.97	0.49	0.9	20	0.70	0.9	0.90
4 - Façade Mur4	1.97	0.49	0.9	20	0.70	0.9	0.90
5 - Toiture Toiture0	1.97	0.49	0.9	20	0.70	0.9	0.90
6 - Toiture Toiture0	1.97	0.49	0.9	20	0.70	0.9	0.90

Uo	Uop	Tu
0.59	0.59	0.77

Figure 6.. the technology window

envelope. The last 3 parameters, alpha, beta, epsilon are optical parameters about the absorbed, transmitted and infrared emission parts of light.

With these last two screens, the programme knows the complete composition of the exchange envelope.

4. The surrounding context description

This graphic window contains first an orientation circle on which the house model can interactively turn in front of the cardinal marks.

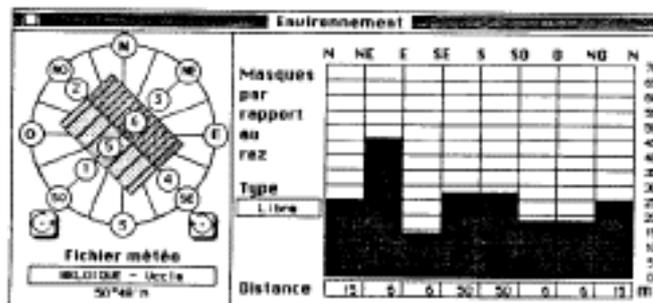


Figure 7: the site description

A second diagram presents the cylindric projection of the environmental site. The user can select a mean type mask (open, suburban, urban) or change the height of each sector solar mask. The window proposes a geographic location (here in Belgium), linked with the appropriate meteorological data file. Just one mouse clic is needed to move the project wherever in Europe!

5. Human occupancy parameters

Two elementary parameters fix the indoor comfort temperature (t_c) and the internal free gains (Q_i) due to the house occupancy (metabolism, artificial lighting...).

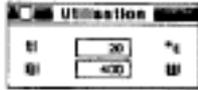


Figure 8: the domestic parameters

User help tools

Strategy is designed to be self consistent. In front of the wide choice of parameter editing, a user is able to manage his project by working with just a few elementary parameters. At the beginning, the programme proposes all default values, corresponding to the mean Belgian house. The user progressively learns the different concepts and only works with those he is actually interested in. He is lead into the work by the error manager which controls all keyboard and mouse inputs.

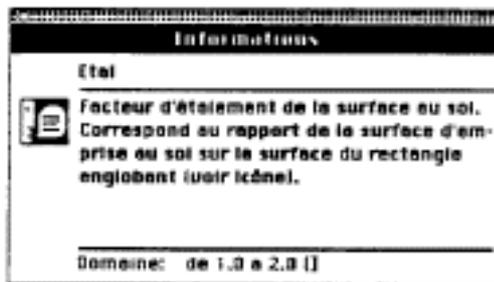


Figure 9: the information panel

To help him discover new concepts, an information panel provides from the glossary the definition of any word displayed on the screen. Further more, this window displays the definition range and the units of the interrogated parameter.

The thermal conduction (U) evaluator is a utility tool available in the technology wall window. Instead of editing the U factor with an arbitrary value, the user can describe the layers of wall compositions by listing the materials used in a real building. This operation can even be performed without looking at the thermal characteristics. From a material catalog, the first part of

Validation and test

The next step of the Strategy II assessment was to see its inherence on the user's learning and behavior. This has also been done with the help of the Department of Educational Technology of our University. This team used the CERT software, which is also a EuroTecNet research programme, to achieve such an evaluation.

The procedure was:

- pretest: to test students about energy building concepts before they use Strategy;
- to put the learners into a training situation and ask them to solve some problems with the Strategy software, - posttest: to test the students again. In comparison with the pretest, the questions are the same but written in another way. Posttest gives us a measure of their learning profit;
- retest: one month later, to test a new time with a large form using the question sets of the pre- and posttest. This questionnaire first evaluates the learning stability. It also assesses the real difficulty of the two previous tests.

These tests were written as multiple choice questions, linked with confidence degrees. Pre- and posttest are each made of nine high taxonomic level questions and test the students' analysis and synthesis capacities.

The answers can be found through written propositions but can also use General Implicit Solutions (GIS) like "all (any) propositions are true", "data lacking or "absurd question". Each answer is linked with a confidence degree from which the CERT software can show how people can assess itself. This operation can be done for the complete test, for each subject question set or for one single question. Hereunder you can find the output given by CERT to the student.

Certitudes	0	25	50	75	100	
Nbre rep	36	14	21	29	20	128
Nbre corr	7	3	8	19	18	63
Nbre incorr	29	11	13	10	2	65
% rep corr	19	21	38	66	90	49
Val centr	12,5	37,5	60,0	77,5	90,0	97,5
Estimation						15,2
Scores:						
rep corr	91	48	136	342	342	1119
rep incorr	116	33	16	9	-12	163
Sévérité -	21					
Score:	11,0/20					Total: 1282/2560
Acuité:	21,952		bon			
Cohérence:	0,944		bon			
Concentration:	5,957		bon			
Réalisme:	0,923		bon			

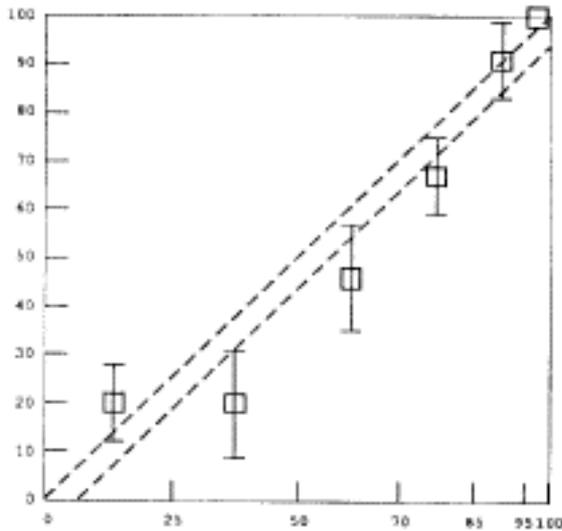


Figure 12: the CERT outputs

The numbers of total correct and incorrect answers for each confidence degree. The R.S. s' (Rates of success) values. Recall of the expected rates of success for each confidence degree (i.e. the central value of each internal degree), The total score, given a severity coefficient.

The four indices of the quality of selfassessment.

The graph of Selfassessment, or realism (points 2, 3, 4, 5, 6 constitute the realism table). Each R.S. is represented by a square. In addition (over and under) to each square (or R.S.) is drawn it's standard error of measurement (SEM).

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The CERT software also gives the correlation between the test results and each item result. Therefore we can find and correct badly written questions and balance the test results for correct comparison. Let's have a look at the overview of collective results. Note that our tested student group consists of only 6 people. No generalization can be deducted from these numbers. Let's consider this only as a first experience which is encouraging for the future.

sujets	prétest	s. pondéré	retest (prétest)	posttest	s. pondéré	retest (posttest)
1.	14,7	19,1	13,6	12,9	22,6	13,5
2.	7,9	10,3	10,1	6,5	11,4	14,3
3.	13,9	18,1	15,7	8,9	15,6	15,1
4.	13,6	17,7	11,4	9,2	16,1	10,1
5.	13,3	17,3	19,9	13,1	23	4
6.	9,6	12,5	21,3	7,4	13	11,5
total	73	95	92	58	101,7	68,5

Figure 13: collective results of the experience

Looking at the results of the posttest, we can see they are worse than those of the pretest. It leads us to believe that the first one was easier. Therefore we have to ponderate the results by the mean performance of each test. We can then see a global gain in the posttest, as well as a better performance for 4 students. The chart shows the knowledge stability with the two parts of the retest, revealing cognitive activity which has allowed students to balance their knowledge. Strategy seems to be adapted to the tested students because the balance is larger in the retest.

This complete test procedure will be realized during the next year with other groups of people like architect engineer students, architect students, professional architects and engineers.

Future developments

The educational module will improve the quality of the information board, following the written thermal courses. It will be based on the card principle and will use the HyperText system.

Exercises will also be proposed on line to verify the understanding of the different concepts explained in this information window. The student evaluation, based on the CERT principle, will be sent back to the user and transmitted to the teacher module.

The teacher module exists at the present time as a historical list of user's actions. For example, it's possible to see how many times this one has asked for information about the shape parameters, how much iteration functions have been drawn. After complex analysis of these lists, the LEMA and the CTE will try to extract the different resolution processes used by the learners. They will infer the main rules which will be proposed in the future intelligent tutorial system (ITS), which will guide and help students to induce the right resolution strategies.

The current development is the writing of a solid modeler. This is a less theoretical tool to design the building shape, but a more powerful one to create the volume of an existing or future house before its thermal evaluation. It will produce a virtual model of the heated volume, linked with the description windows of the actual Strategy programme.

The administrative module, which will follow the performance screen, will write the form asked by the Wallonian Region Authorities as the energy loss diagnostic.

These last two developments want to extend the interest of this software to professional architects. By helping them to check the energy performances of their projects, it will teach them the different concepts used and their overlap interactions. This will give them clearer notions which will avoid bad choice in their future design projects.

To open the Strategy software to the European market, the LEMA hopes to implement adapted calculation modules responding to the different administrative laws of other countries.

Acknowledgements

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Bibliography

A. DUPAGNE:

A computer aided learning programme in the field of passive solar architecture, LEMA ULg, Munich, April 1987.

A. DUPAGNE, P. LECLERCQ:

Stratégie, Rapport final, Convention 88/10751 FG/NC. LEMA ULg, Liège, 1988.

D.LECLERCQ:

Confidence marking, its use in testing, Series of Evaluation Studies, Oxford, Pergamon, 1983.

D.LECLERCQ:

Autoevaluation et connaissance partiell, De Boeck, Brussels, 1990.

A. LORQUET, P. LECLERCQ:

Améliorations de Strategy: didacticiel d'études de sensibilités de performances énergétiques de batiments, Convention 89/31457 AS/NC, LEMA ULg, Liège, 1990.

M. PICARD, G. BRAUN:

Les logiciels éducatifs, Presses universitaires de France. Vendôme, 1987.

J. SOUGNE:

Stratégie, Rapports pédagogiques 1 et 2, Convention 89/31457 AS/NC, Faculté de Psychologie et des Sciences de l'Education, ULg, Liège, 1990 et 1991.

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